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SOIL TYPES AND ARBORESCENT SPECIES OF A SPECIFIC WOODLOT IN OTTAWA COUNTY, OHIO[1]

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Abstract. A woodlot in close proximity to the Davis-Besse Cooling Tower is described in terms of arborescent species composition and distribution in relation to two soil types. Fulton silt loam and Toledo silty clay loam play a role in species distribution as do moisture and nutrient availability. The Toledo soil has more available calcium and magnesium and higher organic matter, clay content and cation exchange capacity. Higher soil moisture levels have a major effect on soil aeration that results in reduced nutrient uptake. Consequently, high arborescent seedling mortality and selectivity is characteristic of the Toledo soil, and many species with rather restricted soil-moisture and soil-aeration tolerances are eliminated. *Celtis occidentalis* appears to be the indicator species of the somewhat better drainage conditions of the Fulton soil. This species seems to avoid the more water saturated conditions characteristic of Toledo soils.

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The plant communities occupying the Navarre Marsh area encompassed by the Davis-Besse Nuclear Power Plant on the shore of the western end of Lake Erie have never been specifically described, although several studies have contained general descriptions of the area. Gordon (1966, 1969), for instance, includes the shoreline area in either the Elm-Ash Swamp Forest or Freshwater Marshes Association, depending upon local topography. Kaatz (1955) includes the area in the eastern boundary of the former "Black Swamp". One partial list of the vascular plants presented in the area was tabulated by Meeks (1973), although no quantitative data were presented.

Similarly, only very general information is available concerning the soils of the area. The Ottawa County Soil Survey (Paschall *et al* 1928) does indicate the presence of 6 soil types in the general region, although the areas covered by each are not precisely defined. The more recent soil map of Ottawa County (Ohio DNR 1974) recognizes a Toledo-Fulton Association for the area under investigation. The present study represents a portion of a comprehensive multifaceted investigation of the various naturally occurring ecosystems present in the area encompassed by the Davis-Besse Nuclear Power Plant, Ottawa County, Ohio. This area will be reevaluated periodically to discern if any vegetational and edaphic changes might be attributed to Cooling Tower operation.

STUDY AREA

The Davis-Besse Nuclear Power Plant property is located in Carroll Township, Ottawa County, at longitude 83° 05′ W and latitude 41° 37′ N. It is bordered on the west by State Route 2, on the east by Lake Erie, on the south by Toussaint Creek and on the north by Locust Point. The total property encompasses 383.5 hectares, of which 236.8 hectares are managed marshland. The Cooling Tower Woods, which is the focus of this study, occupies approximately 1.8 hectares on nearly flat glacial lake plain approximately 173 meters above sea level. The woods is adjacent to, and directly north of, the 146.3 meter cooling tower of the power plant complex.

The climate of the Tower Woods is influenced by the close proximity of Lake Erie, which provides a somewhat longer growing season than is found further inland (Preston 1975). Rocky Ridge, an inland station approximately 15.3 kilometers SW of the plant site, averages 86.84 cm of precipitation annually, with 48.07 cm

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average during the April-to-October growing season, a mean annual temperature of 10 °C, with an average of 17.28 °C during the April-to-October growing season, and average dates of killing frosts of May 1 and October 12, giving frost free season of 165 days. The Danbury Township Station in eastern Ottawa County near Lake Erie and approximately 34 kilometers ESE of the plant site averages 75.50 cm of precipitation annually, with 41.12 cm average during the growing season, a mean annual average temperature of 10.39 °C and an average of 17.56 °C during the growing season, and average dates of killing frosts of April 23 and October 25, giving a frost free season of 185 days (Paschall *et al* 1928).

The substrate or soil parent material represents a surface deposit of lacustrine clay 1.8 to 2.7 meters in thickness overlaying 1.2 to 6.1 meters of clayey glacial till. Dolomite bedrock is present beneath the till at a depth of from 3.1 to 15.3 meters below the surface (Preston 1975). The best developed soils of the area include the Fulton silt loam and the Toledo silty clay loam (Limbird, 1974).

METHODS

A soil sampling station was established in a representative soil area in both the Fulton silt loam and Toledo silty clay loam soil types, and Bouyoucos gypsum soil moisture blocks were buried at 10, 20 and 50 centimeter (cm) levels. Percent available moisture was determined weekly with a Bouyoucos Model BN–2B moisture meter and summarized on a seasonal basis to facilitate the interpretation of differences between the two soil types. Seasonal averages of moisture were calculated using January and February to represent winter, April and May the spring, July and August the summer and October and November the fall. March, June, September and December were considered to be transition months and were not used in the calculations.

Over a period of 2.5 years, soil pH, organic matter content, calcium, magnesium, potassium, phosphorus and cation-exchange-capacity levels were analyzed on a seasonal basis at the 10, 20, and 50 cm levels to determine average values for each of these soil components in each soil type. Chemical analyses were carried out by Harris Scientific, Lincoln, Nebraska using standardized soil testing methods. Soil chemical analyses were based on five composite samples taken during each of the 4 seasons from the two stations at each of the three depths at which instruments for soil moisture had been set up. The average chemical constituent levels were composed of these 5 samples taken over the 10 season time span. Thus, 50 values were used to arrive at each average figure at each of the 3 levels tested. It was felt that the link between soils and the forest community of the Tower Woods could only be revealed by a detailed analysis of soil constituents (Wilde 1958). The chemical constituents were tested for significance using a one way analysis-of-variance at the 0.05 level of significance.

Investigation of the woody plant species of the Cooling Tower Woods was initiated in the spring of 1974. A permanent study area 140 x 100 meters in size was established using 5 ft steel fence posts spaced 20 m apart giving a grid system encompassing 140 permanent 10 x 10 meter quadrants. The grid was located so that a boundary strip of approximately 20 m surrounded the entire woods.

Vegetation was sampled by nested quadrats and within 10 x 10 meter quadrats, arborescent species more than 2.54 cm DBH (diameter at breast height) were recorded by species and DBH. Individuals less than 2.54 cm DBH but more than 3 meters tall were tallied simply by species. The sapling and shrub layer (composed of woody species more than 0.3 m but less than 3 m in height) was sampled in 4 x 4 meter quadrats located in the northwest corners of the larger quadrats. In these the number of individual saplings and shrubs were counted by species. The number of woody seedlings (those less than 0.3 m tall) were recorded by species in 0.5 x 2 meter quadrats placed in the northwest corners of the 4 x 4 meter quadrats.

Calculation of importance values was done by modification of the Curtis and McIntosh (1951) and Buell *et al* (1966) methods as described by Hamilton and Forsyth (1972). They were obtained by totaling the relative overstory values for density, frequency, and dominance, and dividing this total by three. The importance values for all other species considered in the remaining vegetational layers were obtained by dividing the sum of the relative values of density and frequency by 2. Thus, values are comparable in all the vegetational layers sampled, with the maximum importance value in any one layer being equal to 100.

Nomenclature of all species follows that of Fernald (1950). The distribution of species was mapped within each quadrat and matched against a randomness model to test the effects of soil moisture, soil texture, and soil chemistry on the distribution of species (Collinson 1977).

RESULTS AND DISCUSSION

Soil Variables in the Tower Woods. The two basic soil types of the Cooling Tower Woods are the Fulton silt loam and the Toledo silty clay loam. Both soils were developed in lake-deposited silt or silty clay overlying glacial till. The Toledo soil is more poorly drained than the Fulton soil, but surface runoff is slow on both soils due to the nearly level topography. The Fulton soil tends to crack when dry unlike the Toledo soil, but the Toledo soil tends to become seasonally ponded. Toledo soil is characterized by a darker surface color than Fulton soil due to its higher organic matter content.

Horizon depths and designations, horizon textures and horizon colors have been accepted as features that distinguish the two soils from one another (Paschall

1928). In the Tower Woods, horizon depths were measured in centimeters for 25 soil profiles in each of the two soil types examined. Horizon designations were based on the average identifying features of the soils and compared to standard soil profile descriptions for the soils of Northwestern Ohio. Texture was determined using a hydrometer method including clay dispersal with hexametaphosphate and the mechanical analyses were based on the averages of five composite samples for each depth (Table 1). Horizon colors were de-

TABLE 1

Mechanical Analysis of the Toledo and Fulton Soils, Tower Woods Site

Horizon	Depth (cm)	Sand	Silt	Clay
	Toledo			
A_1	0–23	3	62	35
A_2	23–36	2½	60½	37
A_{1g}	36–46	2½	54½	43
B_{2gt}	46–81	2	42	56
B_{3gt}	81–102	2	41	57
	Fulton			
A_1	0–15	9	65	26
A_2	15–25	6½	66½	27
B_1	25–36	3½	67	29½
B_{2t}	36–91	2	58	40

termined from Munsell soil color charts for moist soil samples and 4 basic horizons were distinguished in the Fulton soil and 5 basic horizons in the Toledo soil. An average profile description was compiled for each of the two soils from the groups of profiles examined for the Tower Woods soils (Table 2). Fulton soil profiles and Toledo soil profiles were different in the greater depth of the A_1 horizon, the greater depth of the A_2 horizon, the presence of gleying (g), and the higher clay content of the A_1, A_2, B_1, and B_2 horizons of the Toledo soil. The difference in soil texture was especially important because water retention and the supply of plant nutrients can depend upon relatively small variations in clay and silt content (Wilde 1958). In fact, analyses of composition of plant communities have shown differences in composition to be the result of small differences in the percentage of clay present in the soils (Brown and Curtis 1952; Køie 1951; Redmond 1954; Dyrness and Youngberg 1958). Based on the statistically significant differences established between the two soil types, further tests were considered necessary to determine which soil factors might contribute to vegetation distribution patterns in the Tower Woods.

Results of the chemical analyses, conducted on a seasonal basis over the 2.5 year study period, are summarized in table 3. The organic matter content was significantly greater in the Toledo soil, at the 10 and 20 cm depths, than in the Fulton soil. The higher organic matter content causes the darker color of the surface of the Toledo soil. The organic matter content was not significantly dif-

TABLE 2

Profile Descriptions of the Toledo and Fulton Soils, Tower Woods Site.

Toledo silty clay loam		
A_1	0–23 cm	very dark grayish brown (10YR 3/2), silty clay loam.
A_2	23–36 cm	dark gray (10YR 4/1), silty clay loam.
B_{1g}	36–46 cm	grayish brown (10YR 5/2), streaked with dark gray (10YR 4/1), silty clay.
B_{2gt}	46–81 cm	light brownish gray (10YR 6/2) mottled with olive brown (2.5Y 4/4) and yellowish brown (10YR 5/6), silty clay to clay.
B_{3gt}	81–102 cm	light brownish gray (10YR 6/2) with distinct mottles of olive (5Y 4/3), brown (10YR 5/3), and yellowish brown (10YR 5/6), silty clay to clay.
IIC	102+	calcareous glacial till, clay loam.
Fulton silt loam		
A_1	0–15 cm	dark grayish brown (10YR 4/2), silt loam.
A_2	15–25 cm	gray (10YR 5/1), silt loam.
B_1	25–36 cm	brown (10YR 5/3), silty clay loam.
B_{2t}	36–91 cm	light yellowish brown (10YR 6/4), silty clay loam to silty clay.
IIB_3	91–107 cm	light yellowish brown (10YR 6/4) streaked with reddish brown (5YR 5/4), weathered glacial till, clay loam.
IIC	107+	calcareous glacial till, clay loam.

ferent in the two soils at the 50 cm depth. Organic matter at the 10 cm depth in both soils fluctuated somewhat on a seasonal basis with the peak reached during the summer, especially noticeable in the Fulton soil, and the low point reached in the winter, especially noticeable in the Toledo soil.

The cation exchange capacities of the two soils are closely related to the organic matter content and the clay content of the soils. The cation exchange capacity was significantly greater in the Toledo soil than in the Fulton soil at all 3 depths measured. The significant differences correlated directly with significant differences in organic matter content at 10 and 20 cm depths and in clay content at 10, 20 and 50 cm depths (Table 3). Cation exchange capacity fluctuated to some degree on a seasonal basis in both soils. Summer was the low point, when plants have absorbed most nutrients, whereas fall was the high point, when a renewed supply of leaves allowed for an increase in cation exchange capacity based on the increased decomposition of organic matter.

TABLE 3

Average Chemical Analyses of the Toledo and Fulton Soils, Tower Woods Site

cm depth	10	20	50
	Toledo		
% Organic Matter	8.8*	5.1*	2.5
Cation Ex. Capacity (me/100 g)	31.6*	29.2*	26.8*
Calcium (ppm)	4585	4412*	4113*
Magnesium (ppm)	612*	644*	683*
	Fulton		
% Organic Matter	6.9*	4.6*	2.0
Cation Ex. Capacity (me/100 g)	25.6*	23.8*	22.2*
Calcium (ppm)	4428	3816*	3500*
Magnesium (ppm)	534*	494*	558*

*Statistically significant at the 0.05 level.

The calcium content was significantly greater in the Toledo soil at the 20 cm and 50 cm depths and was directly related to the higher clay content, higher organic matter content and high cation exchange capacity levels. Summer is the season with lowest levels of calcium in both soils and corresponds with the reduction in cation exchange capacity values and the peak time of calcium utilization by vegetation. At all three depths analyzed, magnesium content was significantly greater in the Toledo soil than in the Fulton soil and was closely related to the higher cation exchange capacity and higher organic matter contents (Table 3). Summer is the season with lowest magnesium levels for both soils and corresponds with the period of magnesium uptake and use by vegetation.

Potassium, phosphorus levels and pH values did not vary significantly between the two soils. Potassium values varied from season to season much less than values for other bases. Phosphorus varied considerably from season to season, thus reducing any contrasts between the two soils that may exist when examining the amount of available phosphorus for any single season. Depending on the soil depth or season pH ranged from 6.0 to 7.5. The lowest pH values generally occurred in summer when bases are absorbed by vegetation and higher pH values occurred in the fall when new leaf litter released a new supply of bases.

Seasonal variations in moisture between the two soils showed differences which may affect plant growth and distribution (Table 4). The winter season apparently acts as a period of moisture storage in the Tower Woods and values of less than 100% of available moisture represent freezing of the soil from the surface downward. Since vegetation was dormant during the winter season, moisture levels were relatively unimportant at that time. Analysis of variance showed that there was no significant difference in moisture content in the two soils in winter.

The spring season is a period of moisture levels at or near 100% moisture availability, as melted snow and thawed soils help to contribute to these near field capacity levels. Some evaporation occurred near the surface in both soils. There was no significant difference in moisture content in the two soils in the spring. However, the Toledo soil had

TABLE 4

*Moisture Levels in the Toledo and Fulton Soils, Seasonally and by Depth.**

	10 cm	20 cm	50 cm
Toledo			
Winter	69	89	91
Spring	97	99	100
Summer	15	18**	31
Fall	45	58**	19**
Fulton			
Winter	79	85	89
Spring	98	100	100
Summer	16	10**	32
Fall	62	40**	8**

*Values given as % moisture available.
**Statistically significant at the 0.05 level.

lengthy periods of water ponding each spring which was not observed in the Fulton soil. This period of ponding may be important in differences in time of germination and seedling success rates in the two soils. In fact, the water ponding on the Toledo soil may diminish the supply of nutrients available to the trees and shorten the growing season (Wilde 1958). Such an adverse influence would vary considerably with different tree species and thus would not only affect the rate of growth but also the composition of the forest stand (Wilde 1958; Kellman 1975; Morison *et al* 1948).

In the summer season, moisture levels reach their lowest points because both soils dry from the surface downward due to evaporation and transpiration. The average summer moisture levels at the 10 cm and 50 cm depths were comparable for the two soils, but moisture content in the Toledo soil at the 20 cm depth was significantly greater than in the Fulton soil (Table 4). The greater moisture supply can be explained in part by the greater percentage of clay and organic matter (Tables 1 and 3) in the Toledo soil than in the Fulton soil at the 20 cm depth. This relatively greater availability of moisture in the Toledo soil in summer may be important in the selection of tree species. It has been shown that species differ in response to water supply from shallow, intermediate, and deeper soil levels (Wilde 1958; Whittaker and Woodwell 1969; Køie 1951). Water is especially important in the survival rate of seedlings and saplings during the period of lowest moisture availability. Soil moisture deficits can become critical especially when other factors favor growth, and water undoubtedly controls tree growth more than any other factor. Low water availability is responsible for reduced growth, early leaf fall, die back, and even death of trees (Kozlowski 1958).

Both soils began to gain moisture in the fall, associated with moderate precipitation and reduced actual evaporation rates, as air and soil temperatures declined. The moisture recharge at the 10 cm depth was somewhat more rapid in the Fulton soil than in the Toledo soil, but the difference was not significant and may be attributed to the water permeability and water holding capability of the silt in the Fulton soil. The moisture recharge and moisture levels are significantly higher in the Toledo soil at the 20 cm and 50 cm depths than in the Fulton soil. The greater moisture content at the 20 cm and 50 cm depths may be important in the success of moisture requiring seeds and seedlings and may help to contribute to the water ponding on the Toledo soil in spring.

Arborescent Vegetation of the Tower Woods. The Tower Woods can be characterized as an *Acer negundo* and *Celtis occidentalis* community. Together they represent better than 43% of the total importance value (I.V.) of the tree layer (Table 5). The only other trees of significance in this layer are *Crataegus* sp., *Gleditsia triacanthos*, and *Ulmus rubra*, their combined importance values representing approximately 44% of the total. The sapling layer is composed primarily of *Acer negundo* (I.V. 35.62) and next in importance among the trees is *Celtis occidentalis* (I.V. 3.82). The viney species, *Vitis riparia* and *Parthenocissus quinquefolia*, constitute approximately 25% of the total importance value in this layer. The only shrub species component of any importance is *Ribes americanum* (I.V. 22.37). Arborescent reproduction is dominated by *Acer negundo* and *Celtis occidentalis*, respectively, viney reproduction by *Parthenocissus quinquefolia* and *Vitis riparia*, and shrub reproduction by *Ribes americanum* and *Rhus radicans*.

TABLE 5

Importance Values of Species in the Cooling Tower Woods, Davis-Besse Nuclear Plant Site, Ottawa County, Ohio

	Tree Layer	Shrub & Sapling Layer	Seedling Layer
Acer negundo	23.06	35.62	11.34
Celtis occidentalis	20.35	3.82	9.72
Crataegus sp.	16.96	1.22	4.34
Gleditsia triacanthos	14.92	2.63	0.76
Ulmus rubra	12.92	0.56	1.25
Gymnocladus dioica	3.22	0.30	—
Cornus drummondi	2.95	2.96	3.69
Morus alba	1.41	0.20	—
Robinia pseudoacacia	1.37	—	—
Juglans nigra	0.94	—	—
Prunus serotina	0.73	—	—
Populus deltoides	0.40	—	—
Rhus typhina	0.36	0.30	—
Acer rubrum	0.35	—	—
Fraxinus pennsylvanica	0.31	0.56	—
Prunus virginiana	0.22	0.20	0.25
Ribes americanum	—	22.37	15.90
Vitis riparia	—	14.18	9.64
Parthenocissus quinquefolia	—	11.36	16.81
Rhus radicans	1.67	21.38	—
Rubus occidentalis	—	0.77	0.87
Juglans nigra	—	0.56	—
Solanum dulcamara	—	0.51	4.05
Rosa multiflora	—	0.20	—

It is conceivable that the Tower Woods might be classified as a variation between the transitional phase 2 and phase 3 of the Elm-Ash-Soft Maple community of Sampson (1930). Although *Fraxinus americana*, *Carya laciniosa* and *Quercus macrocarpa* are diagnostic for phase 2, *Gleditsia triacanthos*, *Acer negundo* and *Celtis occidentalis* are listed as infrequent in occurrence. In addition, *Ulmus rubra* enters initially in transitional phase 3 along with *Fraxinus pennsylvanica* and *Gymnocladus dioica* as additional species. These last six species account for almost 75% of the total importance value of this community, and their distribution within this woods appear to be related to soil moisture variations.

The habitat preferences of the different species suggest a moisture-tolerance range from relatively dry to relatively wet in all three vegetation layers (Table 6). For instance, *Acer negundo* is definitely a species characteristic of poorly drained, clay-rich till that may have standing water much of the spring (Meeglin and Ohmann 1973). *Celtis occidentalis*, on the other hand, ranges from dry to mesic in high lime substrates, but tends to outcompete the more mesic species in the somewhat drier stituations (Hamilton and Forsyth 1972). *Gleditsia triacanthos*, *Ulmus rubra*, *Vitis riparia* and *Parthenocissus quinquefolia* all appear to favor more mesic situations, while *Rhus radicans* occurs in drier sites.

The range of species present thus indicates a heterogeneous substrate, at least in terms of moisture. Based on this and on obvious variations between the two soil types previously discussed, specific quadrats located within areas underlain by the two soils were selected for further study. This selected area encompassed 35 nested quadrats located entirely in the Toledo soil and 71 situated in the Fulton soil. The data from these quadrats for the tree layer indicated definite differences in species composition and distribution. The basal area and dominance values for individuals of *Gleditsia triacanthos* occurring in the Toledo soil were almost twice the values for those growing in the Fulton soil. In addition, basal area values and number of individuals of *Ulmus rubra* exhibited the same relationships. In contrast, basal area, dominance, and number of individuals of *Celtis occidentalis*, *Gymnocladus dioica* and *Morus alba* were all usually higher in the Fulton soil.

Importance values were calculated for all species occurring in association with each soil group and these values were then used to evaluate the degree of variation in plant species between the two soil types (Table 7). Studies have demonstrated that in the establishment of plant communities, species populations become differentiated spatially according to their response to habitat variations such as changes in soil conditions that act to separate one species population from another (Collinson 1977; Morison *et al* 1948). In the tree layer, differences in importance values in the two soil areas among 5 species proved to be significant.

TABLE 6

Tree Data for the Fulton and Toledo Soils of the Cooling Tower Woods, Davis-Besse Nuclear Plant Site, Ottawa County, Ohio.

	Total Stems Per Hectare	Total Basal Area Per Hectare	Density	Frequency	Dominance	Relative Density	Relative Frequency	Relative Dominance
	TOLEDO SOIL							
Acer negundo	414	4577.1	4.14	68.57	45.77	31.36	19.20	14.61
Celtis occidentalis	137	1688.8	1.37	68.57	16.89	10.38	19.20	5.39
Crataegus sp.	369	3432.1	3.69	80.60	34.32	27.95	22.40	10.96
Gleditsia triacanthos	32	17914.2	0.31	25.71	179.14	2.35	7.20	57.19
Ulmus rubra	280	3255.2	2.80	77.14	32.55	21.21	21.60	10.39
Gymnocladus dioica	6	60.7	0.06	2.86	0.61	0.45	0.80	0.19
Cornus drummondi	62.9	126.8	0.63	17.14	1.27	4.77	4.80	0.40
Morus alba	2.9	2.2	0.03	2.86	0.02	0.23	0.80	0.01
Robinia pseudoacacia	—	—	—	—	—	—	—	—
Prunus serotina	—	—	—	—	—	—	—	—
Populus deltoides	—	—	—	—	—	—	—	—
Rhus typhina	—	—	—	—	—	—	—	—
Juglans nigra	2.9	215.7	0.03	2.86	2.16	0.23	0.80	0.69
Fraxinus pennsylvanica	11.4	45.7	0.11	8.57	0.46	0.83	2.40	0.15
Prunus virginiana	2.9	5.1	0.03	2.86	0.05	0.23	0.80	0.02
	FULTON SOIL							
Acer negundo	416	6283.1	4.15	71.83	62.84	30.12	22.34	18.21
Celtis occidentalis	311	7533.2	3.11	63.38	75.33	22.57	19.69	21.83
Crataegus sp.	299	4046.5	2.98	57.74	40.46	21.62	17.94	11.73
Gleditsia triacanthos	47	9665.9	0.46	26.76	96.66	3.34	8.31	28.01
Ulmus rubra	123	1419.9	1.23	52.93	14.20	8.92	16.44	4.12
Gymnocladus dioica	75	2400.8	0.74	8.45	24.01	5.37	2.62	6.96
Cornus drummondi	34	82.0	0.34	12.67	0.82	2.47	3.94	0.24
Morus alba	24	611.8	0.24	9.86	6.12	1.74	3.06	1.77
Robinia pseudoacacia	2	1168.5	0.14	1.41	11.68	1.01	0.44	3.38
Prunus seotina	13	486.5	0.13	4.23	4.86	0.87	1.31	1.41
Popular deltoides	3	401.6	0.03	2.82	4.15	0.22	0.88	1.20
Rhus typhina	14	85.8	0.14	2.82	0.86	1.01	0.88	0.25
Juglans nigra	3	297.3	0.03	2.82	2.97	0.22	0.88	0.86
Fraxinus pennsylvanica	4	3.3	0.04	2.82	0.03	0.30	0.88	0.01
Prunus virginiana	3	7.0	0.03	1.41	0.07	0.22	0.44	0.02

Three species, *Celtis occidentalis*, *Gymnocladus dioica* and *Morus alba* were significantly more important in the areas of Fulton soil, while two species, *Ulmus rubra* and *Gleditsia triacanthos* were significantly more important in the areas of Toledo soil. Five species were shown to be significant in the shrub and sapling layer. *Celtis occidentalis*, *Gymnocladus dioica* and *Acer negundo* were more important in areas of Fulton soil. *Cornus drummondi* and *Ribes americanum* were more important in the Toledo soil areas.

In the seedling layer, 7 woody species were identified as exhibiting significant importance values. Four species, *Celtis occidentalis*, *Acer negundo*, *Crataegus* sp. and *Parthenocissus quinquefolia* were more important in the areas of Fulton soil while 3 species, *Ribes americanum*, *Cornus drummondi* and *Rhus radicans* were more important in the Toledo soil areas. Overall, the most diagnostic species seem to be *Celtis occidentalis*, *Acer negundo* and *Gymnocladus dioica* in the Fulton soil while *Gleditsia triacanthos*, *Cornus drummondi* and *Ribes americanum* characterize the Toledo soil areas.

Moisture seems to be more available in the Toledo soil than in the Fulton soil in summer and in fall. Initially, we felt that a consistently higher level of soil

TABLE 7

Importance Values of the Different Woody Species in the Toledo and the Fulton Soils of the Cooling Tower Woods, Davis-Besse Nuclear Plant Site, Ottawa County, Ohio.

	Fulton Soil			Toledo Soil		
	Tree Layer	Shrub & Sapling Layer	Seedling Layer	Tree Layer	Shrub & Sapling Layer	Seedling Layer
Acer negundo	23.56	47.94*	26.43*	21.72	35.67*	11.41*
Celtis occidentalis	21.36*	8.33*	17.28*	11.66*	0.00*	0.00*
Crataegus sp.	17.10	0.00	8.61*	20.44	1.92	2.53*
Gleditsia triacanthos	13.22*	0.00	0.00	22.25*	1.63	0.00
Ulmus rubra	9.83*	0.00	0.00	17.73*	0.00	0.00
Gymnocladus dioica	4.98*	3.16*	0.00	0.48*	0.00*	0.00
Cornus drummondi	2.22	0.00*	2.59*	3.28	5.16*	12.65*
Morus alba	2.19*	0.00	0.00	0.35*	0.00	0.00
Robinia pseudoacacia	1.61	0.00	0.00	0.00	0.00	0.00
Prunus serotina	1.19	0.00	0.00	0.00	0.00	0.00
Populus deltoides	0.76	0.00	0.00	0.00	0.00	0.00
Rhus typhina	0.71	0.00	0.00	0.00	0.00	0.00
Juglans nigra	0.65	0.00	0.00	0.57	0.00	0.00
Fraxinus pennsylvanica	0.40	2.05	0.00	1.13	0.00	0.00
Prunus virginiana	0.22	0.00	0.00	0.35	0.00	0.00
Ribes americanum	—	18.16*	9.35*	—	26.89*	32.98*
Vitis riparia	—	13.50	4.51	—	14.21	5.56
Parthenocissus quinquefolia	—	6.38	19.35*	—	12.90	6.04*
Rhus radicans	—	0.00	11.88*	—	1.63	28.82*

*Significant at 0.05 level.

moisture throughout the year would provide a more stable moisture environment that should be reflected in greater numbers of woody species in areas of Toledo soil as compared to areas of Fulton soil, but this assumption does not seem to hold true. The Toledo soil does have higher moisture levels, particularly at the 20 cm and 50 cm depths (Table 4) and as visually observed in spring ponding. It can be stated, however, that this greater moisture content in summer and fall and delayed drying in spring undoubtedly have a major effect on soil aeration and thus represent an inhibiting factor in species distribution (Wilde 1958; Kellman 1975; Morison *et al* 1948). The near saturation levels and surface ponding of water of the Toledo soil during the spring germination period, coupled with higher moisture levels at depth compared to the Fulton soil during the summer and fall, seem to result in high seedling mortality and seedling selectivity (Køie 1951; Kozlowski 1958; Wilde 1958). Many species with rather restricted soil-moisture and soil-aeration tolerances were shown to be eliminated (Table 7).

Although more calcium and magnesium was available in the Toledo soil than in the Fulton soil (Table 3), the higher moisture content may have an inhibiting effect on such nutrient uptake (Wilde 1958; Kellman 1975; Voigt 1958). Moisture may serve to limit woody species survival in the Toledo soil because of reduced nutrient uptake. Root injury and decreased formation of new roots are associated with low soil aeration (Kramer and Kozlowski 1960). Different species have evolved differing tolerances to the lack of aeration and nutrients (Kellman 1975; Morison *et al* 1948; Brown and Curtis 1952) and the result is a decrease in the rate of mineral uptake by decreasing the absorbing surfaces. The decreased aeration in the Toledo soil seems to fit such a situation.

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